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The Thermal Study of Porcelain Glazes

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THE THERMAL STUDY OF PORCELAIN GLAZES

BY

FRANCIS WILLIAM WALKER, JUNIOR

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THESIS

FOR THE

DEGREE OF

BACHELOR OF SCIENCE

IN

CERAMIC ENGINEERING

COLLEGE OF SCIENCE

UNIVERSITY OF ILLINOIS

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Francis William Walker Jr.

ENTITLED The Thermal Study of Porcelain Glazes

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Ceramic Engineering

R. T. Stull
Instructor in Charge

APPROVED: A. V. Bleininger

HEAD OF DEPARTMENT OF Ceramics

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A THERMAL STUDY IN PORCELAIN GLAZES.

The reason for undertaking this work on porcelain glazes was for the purpose of drawing more definite conclusions as regards some work done in the fall of 1910 by the class in glazes in the Ceramic Department of the University of Illinois.

The study of porcelain glazes as undertaken by the class was centered about Seger cone 4 which was used as the basis of composition.

$$\left.\begin{matrix}.3K_2O) \\ .7CaO)\end{matrix}\right. .4Al_2O_3 \;) \; 4.SiO_2$$

The base was taken as it is; the Al_2O_3 and SiO_2 being varied between the limits of .3 to 1 and 1.8 to 7.2 respectively. By such variations a field of 80 glazes was afforded from which the effect of Al_2O_3 and SiO_2 upon a glaze of given composition could be noted.

The work was accomplished by the use of commercial materials for which the general formulae of composition were used. The glazes were made up by the wet blending process and burned under unsatisfactory condition; the heat variation being from below cone 7 to above cone 9.

In drawing conclusions from the trials, diagram (1) was constructed, the lines of equal molecular ratio being drawn with the idea that they would help to bound the different fields of glazes.

Upon drawing the lines through the glazes in such a way as to bound the fields it was noticed that they conformed to a certain extent with the lines of equal molecular ratio; the deviation being but very slight. To draw such bounding lines ac-

curately it seemed almost evident from the trials that temperature conditions must be taken into consideration. This conclusion lead me to look at the problem from the standpoint of thermal analysis.

Upon looking at the problem in this light I first tried to locate different hypothetical minerals and such points which might indicate maxima of the fusion curve.

The whole group of porcelain glazes, generally considered, centers about the mineral feldspar (Orthoclase). We might therefore expect its composition to play a very important part in the formation of porcelain glazes. The general formula of feldspars is made up of three components, the base, the intermediary and the acid. Such is the case in porcelain glazes and since the composition of the base is constant, the series can be represented on the triaxial diagram with a certain degree of accuracy by considering the K_2O and CaO mutually replaciable. Such an assumption is broad but since the per cent composition of the feldspars with reference to the alkalies and alkaline earths varies quite widely without materially affecting the properties of the feldspar in a decided manner, its use seems justifiable here for drawing at least preliminary conclusions. The molecular ratio of orthoclase is constant at 6. By drawing this line on diagram (1) it is seen to be approximately the dividing line between matts and clear glazes. This might indicate that some mineral of the molecular ratio of 6 played an important part within the glazes.

By noting the fusion conditions, as portrayed in the trials, where such was possible, and drawing conclusion, it seemed very probable that a eutectic existed at the line of molecular ratio of 9, which seemed to want to conform with the line of best glazes; furthermore a possible eutectic might exist in the range of good

matt glazes. Should there be a drop in temperature to the left of the molecular ratio of 6, the chances are that the drop is slight, but it is not absolutely necessary that there should be a eutectic formed in order to produce a good matt. In fact another line of reasoning seemed to fit more closely to the conditions most conducive to the formation of matts. Should there be no drop in the temperature and therefore no eutectic formed, it seems very possible that a matt is formed by the uniting of the two components to form a homogeneous mixture of crystals of the same kind. The work of our minerologists in which they have shown a eutectic to exist between feldspar and flint at 75% feldspar, which if figured into a general formula will give a molecular ratio of approximately 9, seems to lead one further to the conclusion that a eutectic exists along the line of good glazes.

In order to make my above statements clear, I will illustrate what I have said by the use of a characteristic freezing point diagram taken approximately at rightangles to the lines of equal molecular ratio, (see Fig.A). The heavy lines are lines on which I believe solidification might take place and the dotted lines are merely suggestive as to where the curve might go to. The curve it-

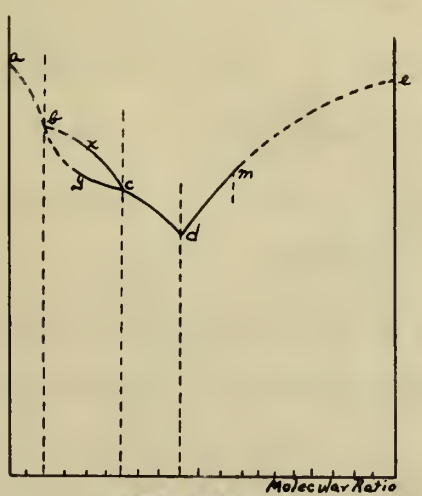


Fig. A.

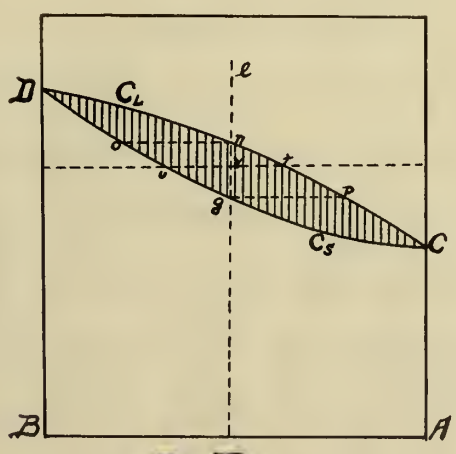


Fig. B.

self is explanatory with perhaps the exception of the area bxcyb. This area may be explained as follows:- Let AC and BD in diagram (B) be the melting points of the two components A and B. In the co-ordinate system, the abscissae denote the percentage contents of the B constituent, and the ordinates temperatures. There is now for each melt a temperature at which mixed crystals begin to separate out. The locus of these points is marked CL (liquidus); this is the line CpnD. Further there exists a second point at which freezing is at an end; these points joined by a line give C, (solidus), CgoD. A certain solution 1 solidifies as follows: at the temperature "n" mixed crystals begin to separate, the content of which, according to the statement expressed above, is smaller than that of the liquid. This content may be found by drawing a horizontal line through "n" which cuts Cs in the point "o". The abscissa of this point gives the B content of the mixed crystals.

By the separation of the crystals rich in B from the solution, this has become richer in A and hence its solidification point falls. At a given instant let this, e.g. be "t"; the crystals separating out at this moment have the composition "u". The mass of the mother-liquor decreases in proportion to the separation of the mixed crystals until finally at the temperature "q" it has become zero. The crystals separating last of all of the composition "q" were crystallized from a mother-liquor of the composition "p".

The originally separated crystals which were poorer in A equalize their composition little by little as they absorb from the mother-liquor a corresponding amount of A, so that finally the whole mass consists of homogeneous mixed crystals of the composition "1". To this end it is of course necessary that the cooling

proceeds so slowly that this enrichment of the already solid mass by diffusion of the constituent A is possible.

The result of the above thought is that I have drawn the following hypothetical conclusions and it is these conclusions that I wish to prove, either wholly or in part, by this thesis.

1. That matt glazes are formed from igneous solutions having a molecular ratio not exceeding 6 and consists when cooled very slowly of a homogeneous mixture of crystals.

2. That bright glazes are formed on cooling, of igneous solutions having a molecular ratio of at least 6 and not exceeding 12 and consists of a eutectic mixture, existing in a state of a homogeneous solid solution.

3. That fusion is a function of oxygen and molecular ratios. With decreasing oxygen ratio there is a percentage increase in the base and a decrease in fusion. The molecular ratio lines within the field of porcelain glazes bound respective fusion conditions.

4. That the general properties of a glaze are a direct function of the molecular ratio and seem to follow in no general way the lines of equal oxygen ratio.

In order to accomplish the above work the following field of work was outlined. The field was laid out upon a triaxial diagram using the vertices to represent the base, the intermediary, and the acid respectively. That portion of the triaxial including a molecular per cent of RO ranging from 35% to 5% and lying between the molecular ratio of 4 and 14 was taken as sufficient to cover the entire field necessary to draw the above conclusions. By molecular ratio is meant the ratio of the molecules of Al_2O_3 to the molecules of SiO_2. The molecular percent of RO was varied

at the rate of 5% thus giving seven different series across the field. The molecular ratios were varied as follows: 4,5,6,7,8, 9,1o, 12 and 14.

In accomplishing the above work, the following outline of procedure was adhered to.

1. The weighing out of the raw materials which constitued the batch.

2. The mixing of the raw material and the fritting of the same.

3. The grinding of the fritts and preparation of the cones.

4. The fusion of the cones.

5. The determination of the physical properties of the glaze when adhered to a white ware body and the maturing temperature of such.

1. The Weighing Out of the Raw Materials.

In order to draw accurate conclusion from any field of work or investigation it is absolutely essential that the actual conditions existing must be known. To accomplish this, the first condition which had to be decided upon, was the composition of the base. It was desired to keep the base as near the composition of $\begin{matrix}.3K_2O \\ .7CaO\end{matrix}$ as possible for the simple reason that the fewer constituents which go to make up the glaze, the easier will it be to draw conclusions. It is impossible to get this base and use commercial materials for the commercial materials contain both Sodium and Magnesium. The base decided upon was as follows:

$$\begin{matrix}.3Na\text{-}KO \\ .7\ Ca\text{-}MgO_2\end{matrix}$$

and by refering to the commercial materials which were to constitute the batch, the following limits were figured to be the min-

imum Na_2O and MgO that could be added and still have the majority of the glazes made of commercial materials.

.21 K_2O)
.09 Na_2O)
.67 CaO)
.03 MgO)

The materials used in making up the batch weights were as follows:

K_2CO_3 - C.P.
Na_2CO_3- C.P.
$CaCO_3$ - C.P.
$MgCO_3$ - C.P.
Clay - North Carolina Kaolin

.0321 K_2O)
.0225 Na_2O) 1.0000Al_2O_3 ((1.935 SiO_2
.0136 Ca_2O) .0090Fe_2O_3 (
.0216 MgO)

Feldspar (potash)

.5283 K_2O)
.1480 Na_2O) 1.0000 Al_2O_3 ((6.655 SiO_2
.0998 CaO) .0075 Fe_2O_3 (
.0228 MgO)

The spar were analized in the chemistry department of the University of Illinois.

The materials were weighed out upon a pair of balance sensitive to the third decimal place, but care was only taken to get the weighing correct to the second decimal place. In all 200 grams of each glaze was made up.

2. The Mixing and Fritting of the Raw Materials.

In order to secure good homogeniety and also to free the mixes of their contained gases and moisture, so as the cones would remain compact during fusion, it was deamed advisable to fritt all mixtures. This was accomplished by first thoroughly mixing the glaze by passing them from four to six times through a 20 mesh sieve. They were then placed in Battersea crucibles and fused down to a glass which was poured out upon a concrete slab and allowed to cool in the air. It is not likely that there was any union between the concrete and fritt for the fritt was quite viscous and cooled considerably before reaching the concrete. This procedure of fritting was only possible however in the case of the first 28 mixed (from glaze 1010-1612) for above that the crucibles would not hold up against the necessary heat required for fritting the mix to such a fluid state as to leave the crucible. The remaining mixtures were fritted in porcelain cups by placing them in a kiln. In many cases the fritts were not completely fused on account of the high temperatures required, but all fritts assumed a vitreous appearance. The mixes ranging between 1612 - 2010 were burned to cone 7, and the remaining ones to cone 11. The high shrinkage of the glazes caused them to pull away from the sides of the cup and there was but a small area of contact between the glaze and the cup to permit of contamination.

3. The Grinding of Fritts and the Preparation of the Cones.

In order to make up the glazes into cone it was necessary first that the fritts be ground to a uniform size. This was accomplished by first passing them through a jaw-crusher and

then reducing them further by the aid of an iron mortar and pestle. The fritt was first made to pass through a twenty mesh sieve after which the metallic particles, derived by the reduction, were removed by means of a strong magnet. The material was next placed in a ball mill and allowed to gring for three hours which time was found to be sufficient to reduce the twenty mesh fritt to a size which would all pass a 100 mesh sieve. The powdered substance was molded into tetrahedral pyramids of about 5/8 of an inch in height. The material used to supply the bonding power to the powdered fritt was Gum-Tragacanth. The cones were next placed in a small labratory kiln and the temperature carried to about 600 or 700 degrees C. in order to burn out the organic matter supplied by the use of the gum.

4. The Fusion of the Cones.

The fusion of the cones was accomplished by the aid of a small platinum foil resistance furnace, the base of which was horizontal. The door of the furnace was made of an insertable fire-clay plug which had a 5/8" hole through it which permitted of the observation of the cone. The temperature of fusion was read by means of a platinum,- platinum-rhodium thermo-couple and a millivoltmeter of the Seimen,-Halske type, both of which were standardized especially for this work. The couple was lead into the furnace by small holes in the insertable plug and the junction was made to come within at least one-half inch of the cone. In order to secure accurate results the cold ends of the couple were kept in ice-water.

The observation of the cone during the melting was made by means of a telescope which was placed about 4 feet in front of the furnace and which brought the cone clearly before the eye at

all heats even as high as 1600°C. The use of the cross-hairs within the telescope aided greatly in determining the rate of softening and the standard condition of the final melt.

In order to have all cones of a standard degree of fluidity it became necessary to decide upon some final condition of the melt to which the cones should be fused, and that temperature recorded. This condition was taken as that point at which the apex of the cone bend down sufficiently to touch the supporting base. This condition was not approached by all cone mixes for in some cases the material tended to squat rather than bend. In this latter case the state of fusion was taken as that at which the apex of the cone would be equal in height to the spring of the arch formed by the bent cone.

The fusions were accomplished by placing the cones upon a little piece of platinum foil bent so as to form a support and then placed within the furnace. The furnace temperature was raised rapidly to within approximately 100°C of the softening temperature, and beyond that it was carried up at about the rate of $2\frac{1}{2}$ to 3° per minute until fusion was reached. At the temperature at which the cone seemed to give way the rate was slowed down materially in order that the temperature might be more accurately determined. In the case of the high RO glazes the point of fusion was quite definitely fixed but in those low in RO and high in SiO_2 the fusion was not so definitely marked because of a high state of viscoscity.

5. The Determination of the Physical Properties of the Glaze.

This work as outlined was not accomplished because of a lack of time. The fact that this work was not done handicaps me

greatly in my conclusion but I shall endeavor to draw my conclusions by the aid of diagram (I) which work, as has been said before, was done by the class in glazes.

The field of work as outlined is covered by the following mixes:

Molecular Formulae for Porcelain Glaze Mixes.

No. of Gl.	K_2O	Na_2O	CaO	MgO	Sl_2O_3	SiO_2
1010	.21	.09	.67	.03	.124	1.733
1012	"	"	"	"	.143	1.717
1014	"	"	"	"	.169	1.689
1016	"	"	"	"	.186	1.670
1018	"	"	"	"	.2066	1.650
1020	"	"	"	"	.232	1.620
1022	"	"	"	"	.2653	1.590
1024	"	"	"	"	.310	1.545
1026	"	"	"	"	.372	1.485
1210	"	"	"	"	.1555	2.180
1212	"	"	"	"	.180	2.153
1214	"	"	"	"	.212	2.120
1216	"	"	"	"	.234	2.100
1218	"	"	"	"	.259	2.072
1220	"	"	"	"	.291	2.040
1222	"	"	"	"	.333	2.000
1224	"	"	"	"	.389	1.940
1226	"	"	"	"	.467	1.870
1410	"	"	"	"	.200	2.800
1412	"	"	"	"	.231	2.770
1414	"	"	"	"	.273	2.730

Molecular Formulae for Porcelain Glaze Mixes. (Cont.)

No. of Gl.	K_2O	Na_2O	CaO	MgO	Sl_2O_3	SiO_2
1416	.21	.09	.67	.03	.300	2.700
1418	"	"	"	"	.333	2.664
1420	"	"	"	"	.376	2.630
1422	"	"	"	"	.430	2.570
1424	"	"	"	"	.500	2.500
1426	"	"	"	"	.600	2.400
1610	"	"	"	"	.267	3.730
1612	"	"	"	"	.398	3.690
1614	"	"	"	"	.364	3.640
1616	"	"	"	"	.400	3.600
1618	"	"	"	"	.445	3.550
1620	"	"	"	"	.500	3.500
1622	"	"	"	"	.571	3.430
1624	"	"	"	"	.666	3.333
1626	"	"	"	"	.800	3.200
1810	"	"	"	"	.378	5.280
1812	"	"	"	"	.435	5.220
1814	"	"	"	"	.515	5.150
1816	"	"	"	"	.566	5.100
1818	"	"	"	"	.630	5.040
1820	"	"	"	"	.710	4.960
1822	"	"	"	"	.810	4.850
1824	"	"	"	"	.935	4.670
1826	"	"	"	"	1.132	4.540
2010	"	"	"	"	.600	8.340
2012	"	"	"	"	.691	8.300

Molecular Formulae for Porcelain Glaze Mixes. (Cont.)

No. of Gl.	K_2O	Na_2O	CaO	MgO	Sl_2O_3	SiO_2
2014	.21	.09	.67	.03	.820	8.200
2016	"	"	"	"	.900	8.100
2018	"	"	"	"	1.000	8.000
2020	"	"	"	"	1.123	7.860
2022	"	"	"	"	1.283	7.700
2024	"	"	"	"	1.500	7.500
2026	"	"	"	"	1.800	7.200
2210	"	"	"	"	1.268	17.710
2212	"	"	"	"	1.460	17.450
2214	"	"	"	"	1.725	17.25
2216	"	"	"	"	1.900	17.10
2218	"	"	"	"	2.110	16.90
2220	"	"	"	"	2.380	16.60
2222	"	"	"	"	2.720	16.30
2224	"	"	"	"	3.160	15.80
2226	"	"	"	"	3.800	15.20

The results of the softening temperature, as determinated, are contained in the following figures:

Softening Temperature of Porcelain Glazes.

No.Gl.	OR.	M.R.	%RO	$\%Al_2O_3$	$\%SiO_2$	Softening Temp.	Avg.
1010	2.53	14	35	4.33	60.67	1272 1257	1265
1012	2.40	12	35	5.00	60.00	1273 1275	1274
1014	2.24	10	35	5.91	59.09	1315 1310 1310	1312
1016	2.15	9	35	6.50	58.50	1330 1312 1326	1323
1018	2.04	8	35	7.22	57.58	1330 1323	1327
1020	1.92	7	35	8.13	56.87	1315 1318 1328 1323	1321
1022	1.77	6	35	9.29	55.71	1305 1320 1328 1318	1318

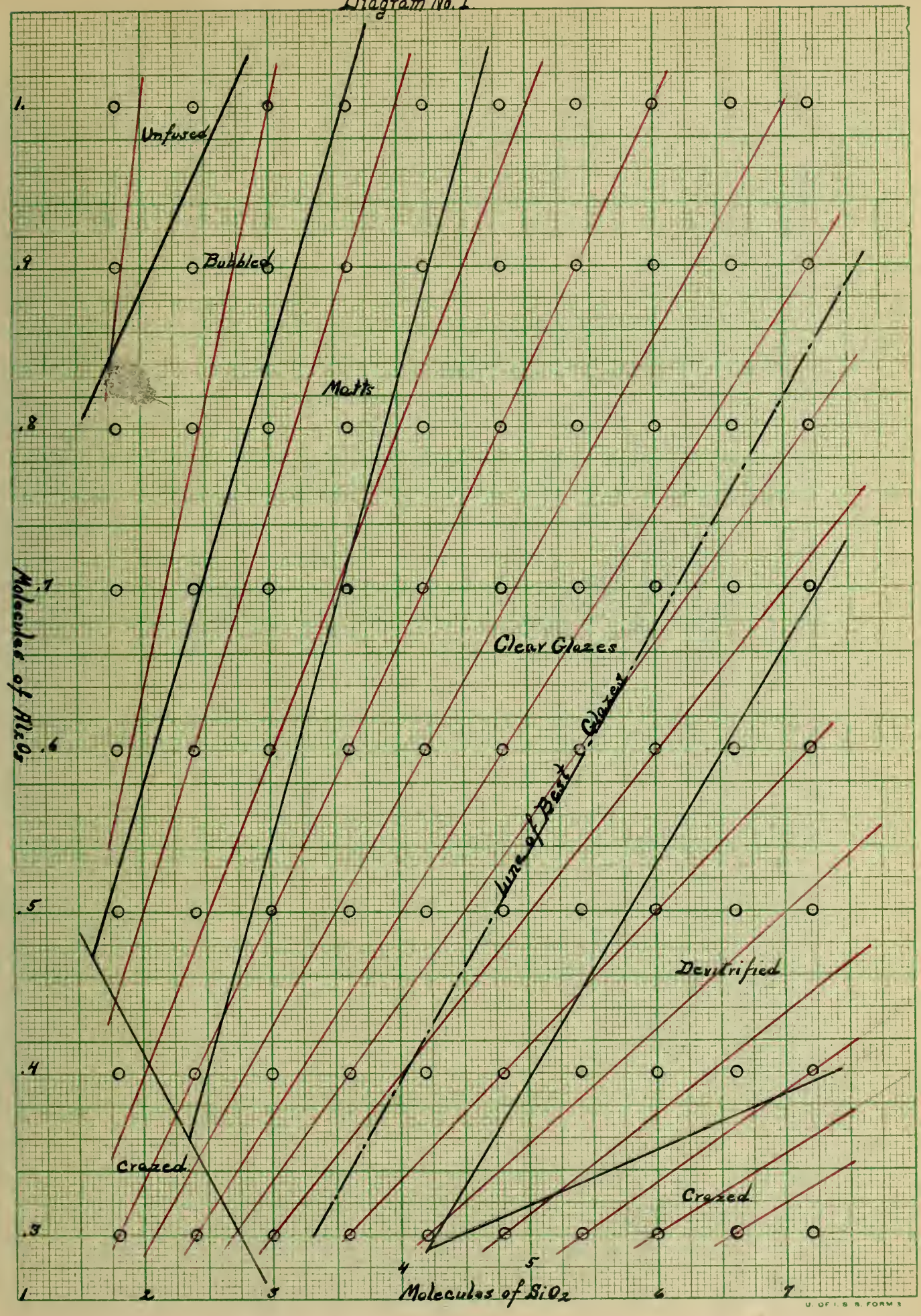
Softening Temperature of Porcelain Glazes. (Cont.)

No.Gl.	OR.	M.R.	%RO	$\%Al_2O_3$	$\%SiO_2$	Softening Temp.			Avg.
1024	1.61	5	35	10.8	54.2	1300	1307		1304
1026	1.41	4	35	13.4	52.00	1272	1272	1272	1272
1210	2.97	14	30	4.67	65.33	1220	1222		1221
1212	2.80	12	30	5.38	64.62	1280	1284		1282
1214	2.59	10	30	6.36	63.64	1260	1268	1264	1264
1216	2.47	9	30	7.00	63.00	1257	1258		1258
1218	2.33	8	30	7.77	62.22	1287	1289		1288
1220	2.18	7	30	8.75	61.25	1297	1305		1301
1222	2.00	6	30	10.00	60.00	1328	1318		1323
1224	1.80	5	30	11.66	58.34	1288	1290		1289
1226	1.56	4	30	14.00	56.00	1275	1271		1273
1410	3.50	14	25	5.00	70.00	1185	1165	1180	1175
1412	3.27	12	25	5.77	69.23	1195	1180	1203	1193
1414	3.00	10	25	6.82	68.18	1185	1190	1195	1190
1416	2.84	9	25	7.50	67.50	1173	1190	1192	1185
1418	2.67	8	25	8.33	66.67	1220	1210		1215
1420	2.48	7	25	9.38	65.62	1245	1257		1251
1422	2.25	6	25	10.71	64.29	1270	1280		1275
1424	2.00	5	25	12.50	62.50	1245	1258		1252
1426	1.71	4	25	15.00	60.00	1215	1260	1260	1245
1610	4.15	14	20	5.33	74.67	1170	1208		1189
1612	3.84	12	20	6.15	73.85	1315	1280		1298
1614	3.48	10	20	7.27	72.73	1285	1270	1280	1278
1616	3.27	9	20	8.00	72.00	1260	1260		1260
1618	3.05	8	20	8.89	71.11	1250	1255		1253
1620	2.80	7	20	10.00	70.00	1235	1245	1240	1240
1622	2.53	6	20	11.43	68.57	1238	1232		1235
1624	2.22	5	20	13.33	66.67	1222	1214		1218

Softening Temperature of Porcelain Glazes. (Cont.)

No.Gl.	OR.	MR.	%RO	$\%Al_2O_3$	$\%SiO_2$	Softening Temp.			Avg.
1626	1.88	4	20	16.00	64.00	1270	1250		1260
1810	4.95	14	15	5.67	79.33	1280	1285		1283
1812	4.53	12	15	6.54	78.46	1310	1306		1308
1814	4.05	10	15	7.73	77.27	1258	1290	1290	1279
1816	3.78	9	15	8.50	76.50	1243	1290	1285	1273
1818	3.49	8	15	9.33	75.67	1230	1265	1265	1253
1820	3.17	7	15	10.63	74.37	1280			1280
1822	2.84	6	15	12.14	72.86	1350			1350
1824	2.46	5	15	14.17	74.83	1320			1320
1826	2.06	4	15	17.00	68.00	1405			1405
2010	6.00	14	10	6.00	84.00	1328			1328
2012	5.40	12	10	6.97	83.03	1320			1320
2014	4.74	10	10	8.18	81.82	1390			1390
2016	4.38	9	10	9.00	81.00	1370			1370
2018	4.00	8	10	10.00	80.00	1382			1382
2020	3.60	7	10	11.25	78.75	1457			1457
2022	3.18	6	10	12.86	77.14	1430			1430
2024	2.72	5	10	15.00	75.00	1460			1460
2026	2.25	4	10	18.00	72.00	1540			1540
2210	7.39	14	5	6.33	88.67	1562			1562
2212	6.51	12	5	7.31	87.69	1558			1558
2214	5.59	10	5	8.64	86.36	1536			1536
2216	5.10	9	5	9.50	85.50	1583			1583
2218	4.64	8	5	10.56	84.44	1562			1562
2220	4.09	7	5	11.88	83.12	1517			1517
2222	3.56	6	5	13.57	81.43	1507			1507
2224	3.02	5	5	15.83	79.17	1560			1560
2226	2.45	4	5	19.00	76.00	1580			1580

Diagram No. I.



U. OF I. S. S. FORM 3

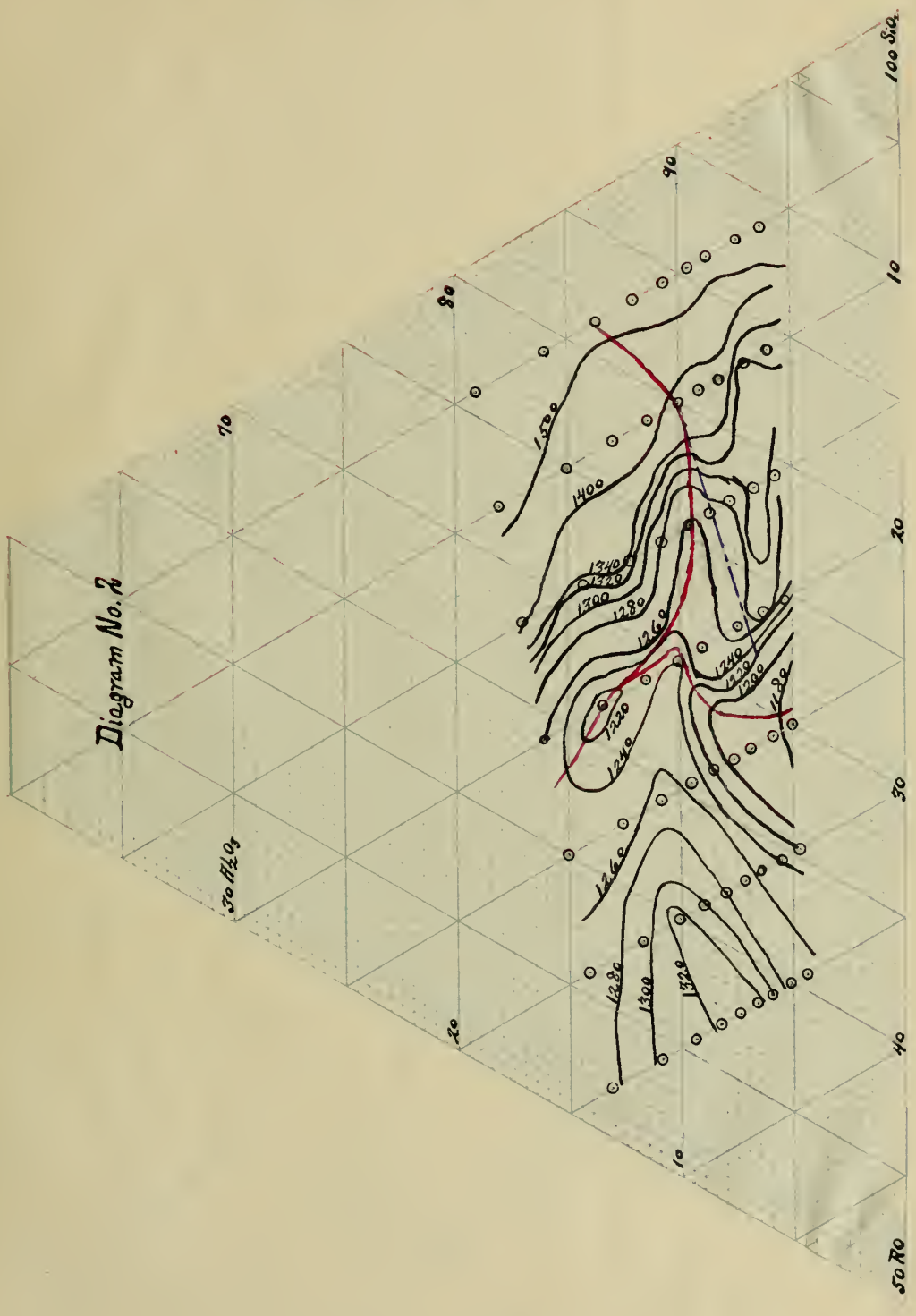
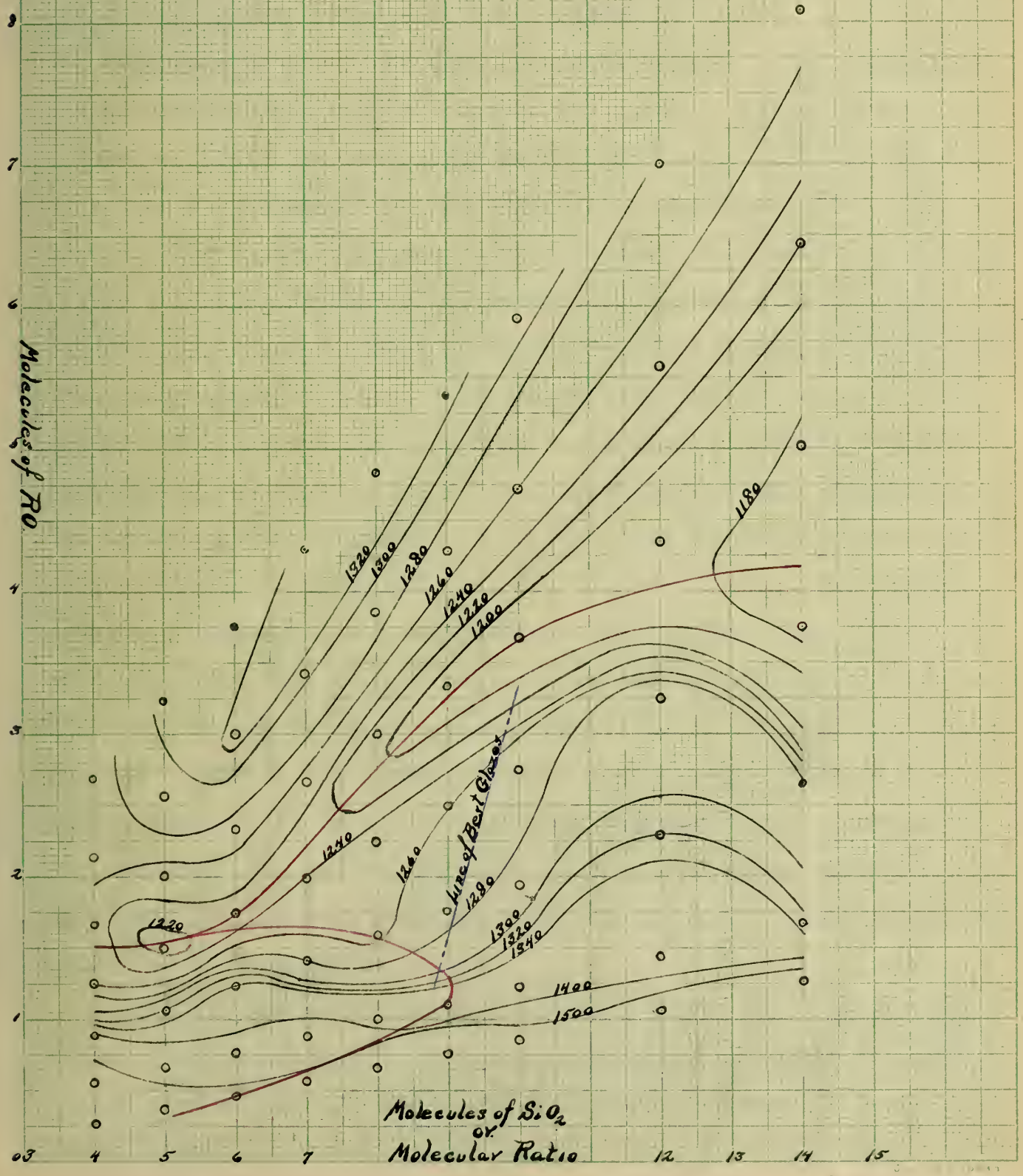


Diagram No. 2
30 Al2O3
70
80
90
100 SiO2
10
20
30
40
50 RO
1500
1400
1340
1320
1300
1280
1260
1340
1320
1300
1280
1320
1240
1360
1280
1300
1320

Diagram No. 3


Molecules of RO
Molecules of SiO_2
or
Molecular Ratio
1320
1300
1280
1260
1240
1220
1200
1180
1240
1220
1260
1240
1300
1320
1340
1400
1500
Line of Best Glazes

The graphical representation of the work is shown by the following curves. The black lines on both diagrams (2) and (3) represent isothermal lines of fusion and the red lines are lines drawn through the mix of minimum fusion for any given molecular per cent of RO. The lines in blue ink represent the line of best glazes as determined by work represented in diagram (1).

The conclusions to be drawn from the work thus far completed are portrayed clearly by the curves given in the accompanying diagrams. The isothermal lines seem to follow no definite direction in either diagram but run irregularly throughout the field. The red line on the diagrams which represents minimum fusion for any given molecular percent of RO seems also to follow no definite direction as regards either molecular ratio or molecular percent of RO. By comparing the blue lines which represent the line of best glazes, with the red line there is no conformity except at the extreme upper end of the line which represents that glaze containing approximately 12½ percent RO. The lower end of the blue line also approaches the red line but does not conform with it. This latter condition might have been met however had the field of work covered by diagram (1) been large enough to include that portion of the field cut by the red line. It is impossible to say from the work done as to whether this nonconformity might be overcome had the glazes represented by diagram (1) been fired at their proper maturing temperatures and therefore the line of best glaze more accurately drawn. Had it been possible to carry the work to completion this matter would have cleared itself.

The statement that matt glazes are formed from igneous solutions having a molecular ratio not exceeding 6 and consist when cooled very slowly of a homogeneous mixture of crystals, remains

unproven. It is very doubtful however that the line of a molecular ratio of six furnishes a bounding line for good matts. The chances are that the line does form a rough boundary for those glazes, represented by the upper right hand portion of diagram (2), but for those glazes to the extreme left this rule would not hold, for the cones of the glaze in that portion of the field, upon fusion, all revealed very soft and pleasing matt textures. The supposed ridge formed by maximum fusion conditions along the molecular ratio line of 6 and which was expected to form the dividing line between good matts and good clear glazes did not put in any definite appearance.

What has been said about the matts may also be applied to the conclusion to be drawn with reference to the clear glazes. If the line of good clear glazes is to follow the line of minimum fusion for any given molecular percent of RO then the statement that good glazes would fall upon the line of a molecular ratio of 9 and that these bounding lines would be the lines of the molecular ratios of 6 and 12, is not correct as shown by the diagrams. On the other hand, should the line of best glazes fall upon the line of a molecular ratio of nine, then the statement that good clear glazes consist of a eutectic mixture existing in a state of a homogeneous solid solution is incorrect, providing that the point of softening of the mixes, as chosen, stands as a comparative point for that change in the physical state of a substance where it passes from a solid to a mobile liquid.

To state that fusion is a direct function of the oxygen and molecular ratios is incorrect. This is shown very clearly by the curves. To state that with decreasing oxygen ratio there is a decrease in fusion is only partially correct for the mixes having

a molecular percent of base above 25 (increasing RO is accompanied by decreasing oxygen ratio) show an increase in fusion. To state that the molecular ratio lines within the field of porcelain glazes bounds fusion conditions for any given per cent of RO is incorrect as shown by the curves.

The general properties of a porcelain glaze are neither a direct function of the molecular or oxygen ratios but can only be represented by a function of a higher degree. This is evident by noting the direction of the red line.

To summarize the work done, it may be said that the hypothetical conclusions as drawn at the time of the outline of the work, remain proven or disproven only in part and that more work must be done on the field before any more definite conclusions can be drawn.

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